Warm Season Drought Development over North America: The Role of Stationary Rossby Waves

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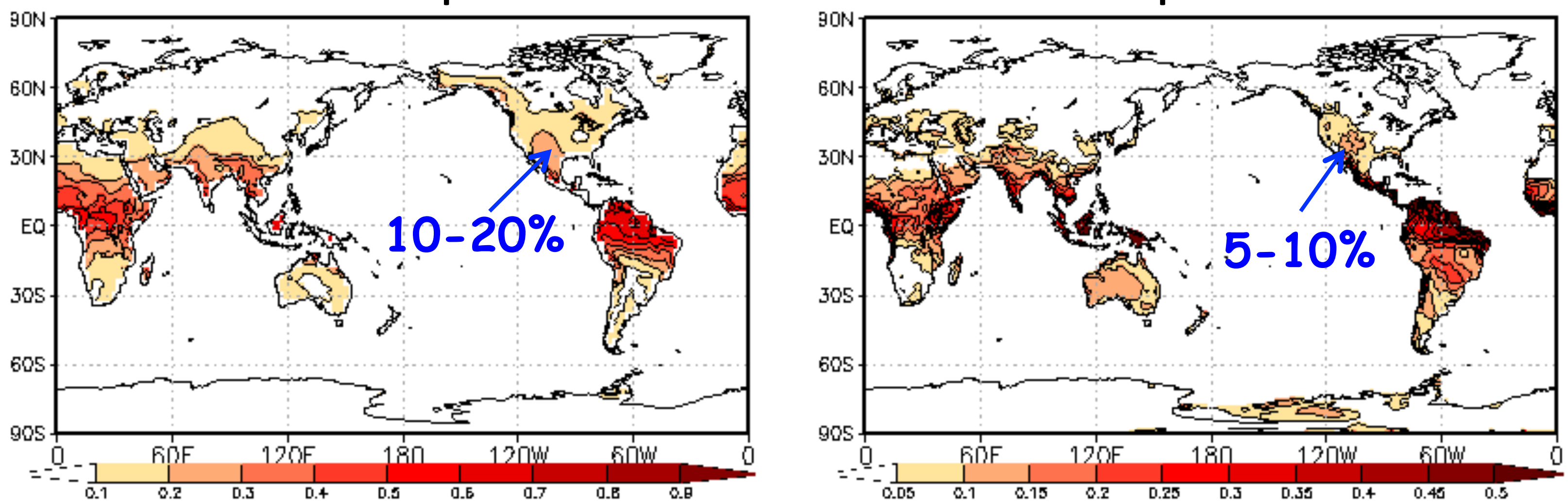
Wang, Schubert, Koster 2016: The Role of Stationary Rossby Waves in the Development of Drought over North America and Links to Northern Eurasia. AGU Book "Patterns of Climate Extremes: Trends and Mechanisms". In press.

Motivation

Variance Ratio: SST/Total
JJA; Interannual

Surface Temperature — Precipitation



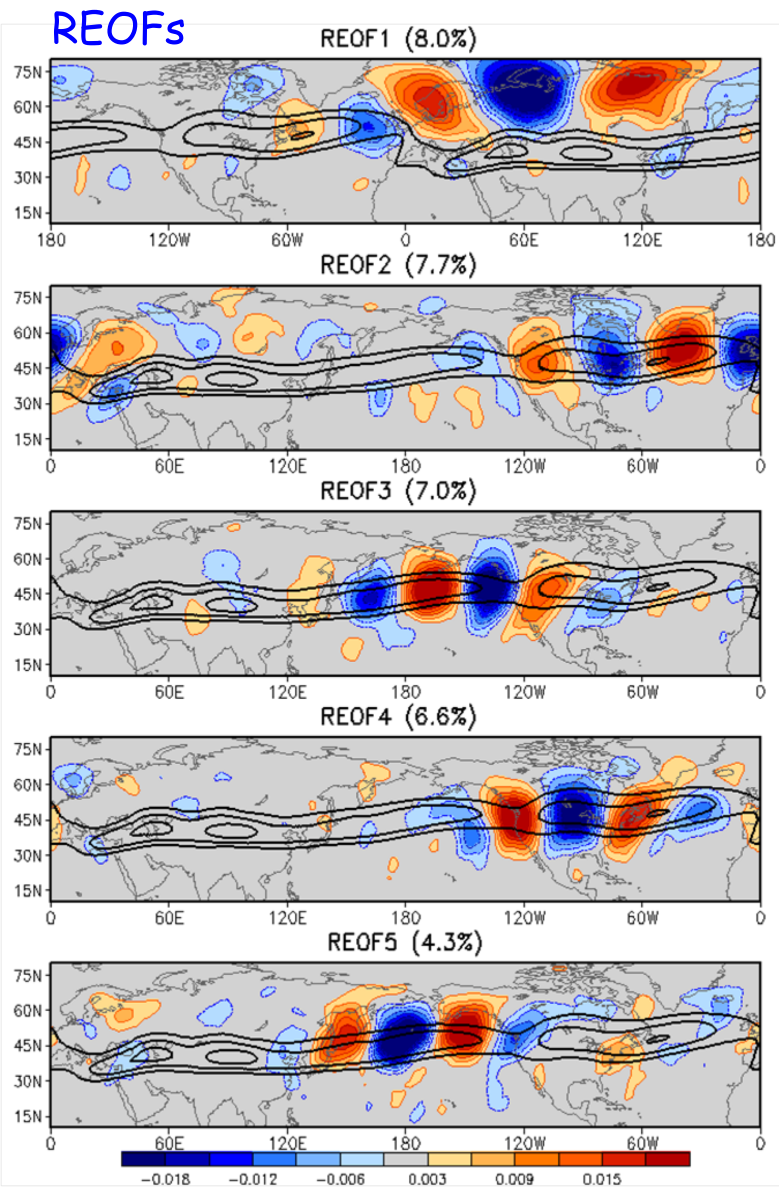
Estimated from 5 AGCMs (GEOS-5, CCM3, CAM4, GFS, ECHAM5)
60 AMIP ensemble members (12 per model); JJA (1979-2011)

Processes that drive warm season drought over North America:

1) Overall weak contribution from SST
    1) Summertime mean flow inhibits influences of remote forcings from tropics
2) Need to better understand processes other than SST, and explore other potential sources of predictability => stationary Rossby waves

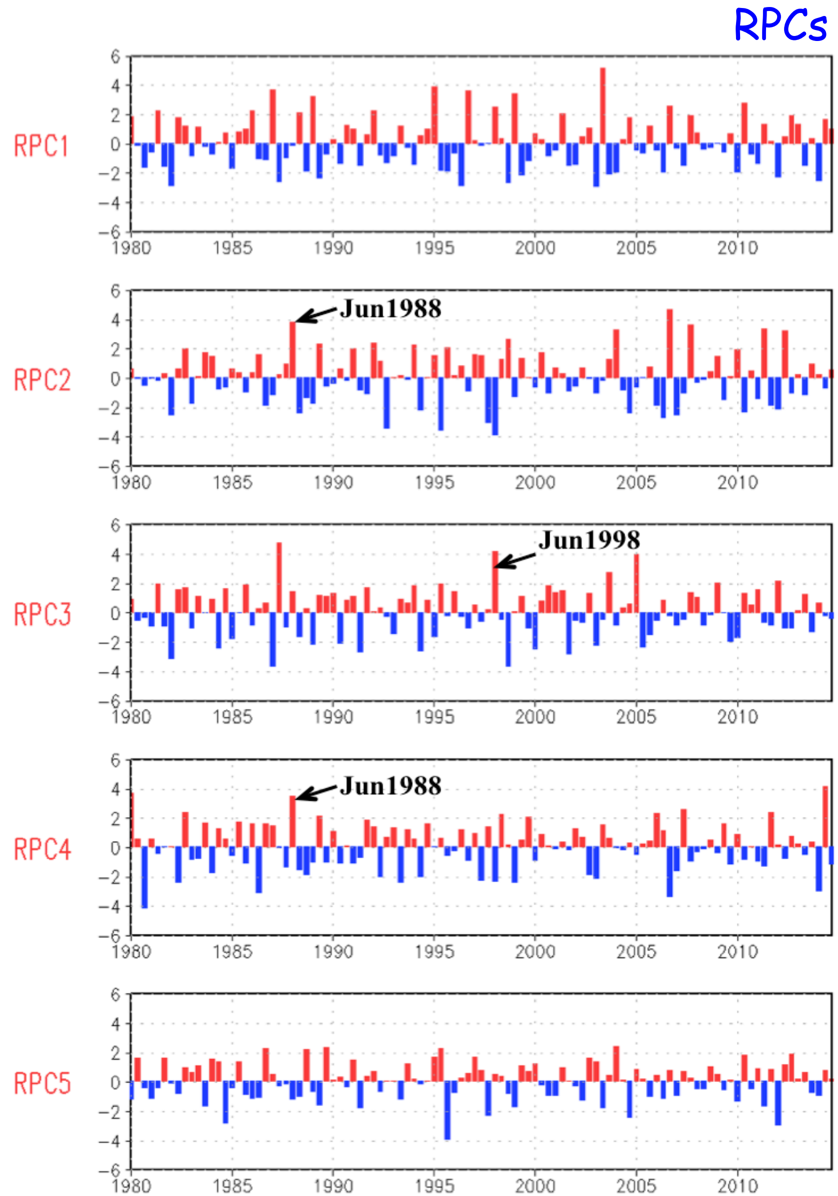
Leading modes of subseasonal atmospheric circulation variability

REOF analysis of summer subseasonal V250mb (MERRA)



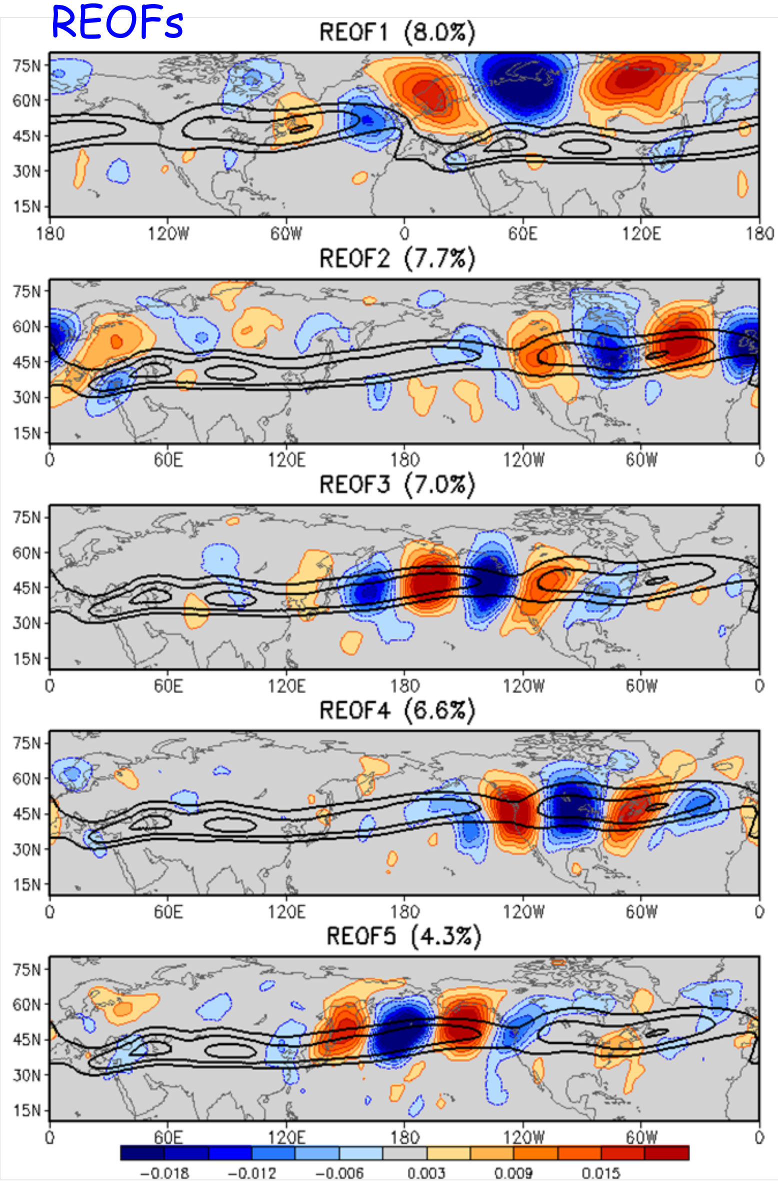
Shaded: REOFs; Contour: JJAClim U250

Strong guidance by NH mean jets



Identify climate extreme events from the RPCs

Leading modes of subseasonal atmospheric circulation variability



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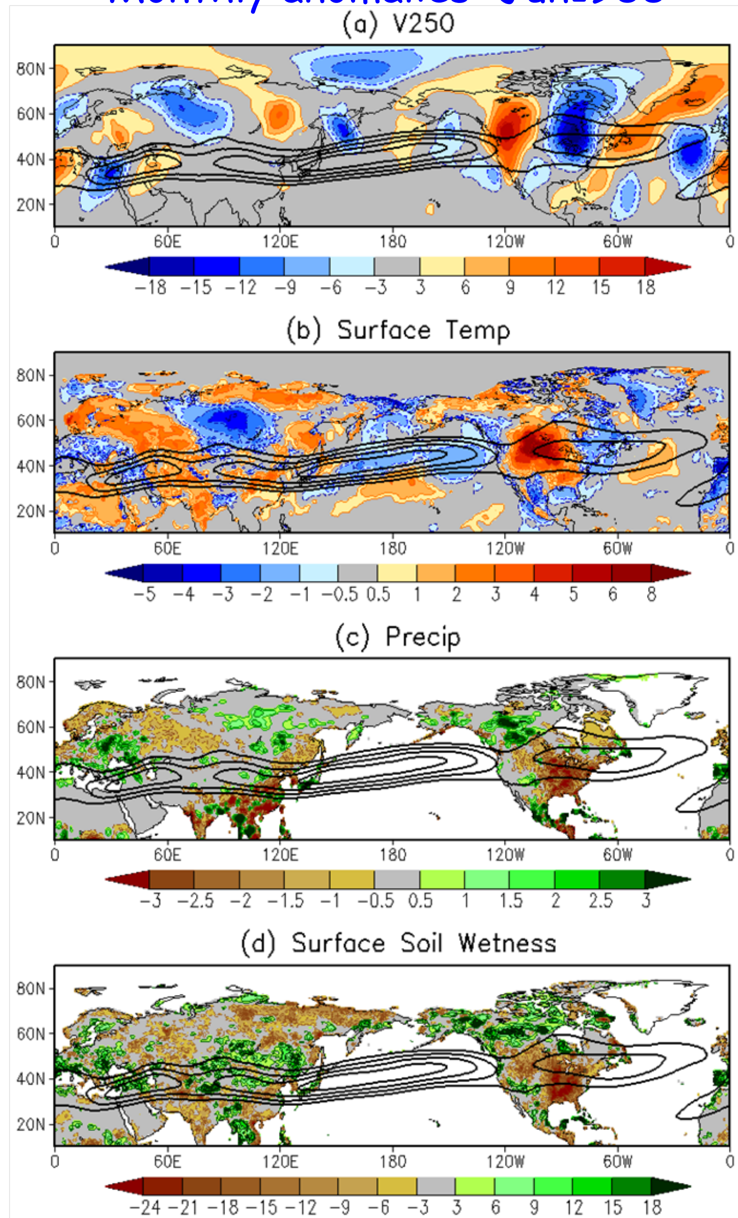
Strong guidance by NH mean jets

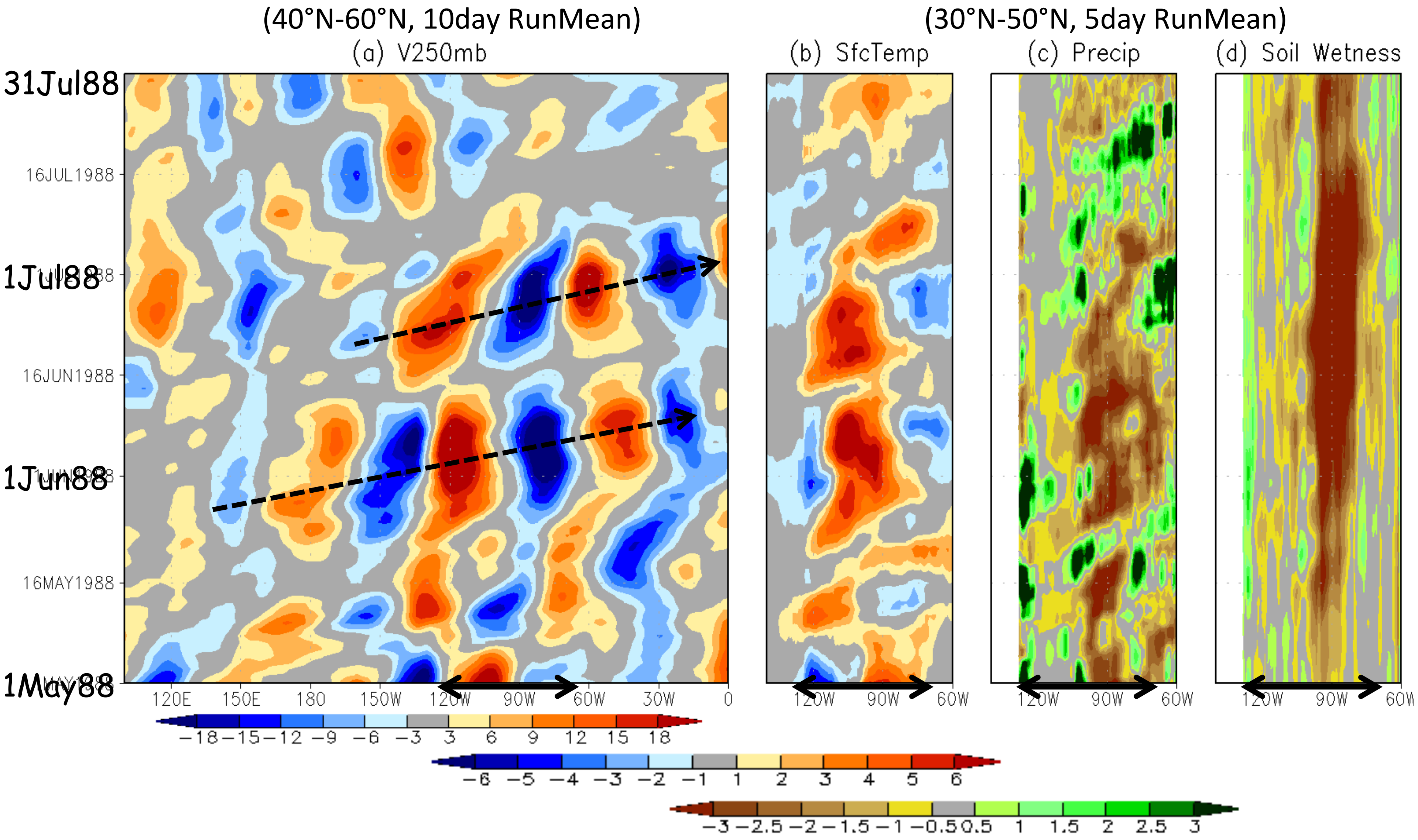
Monthly anomalies: Jun1988



MERRA

MERRA land

Temporal Evolution of Daily Anomalies (MERRA/MERRA_Land)

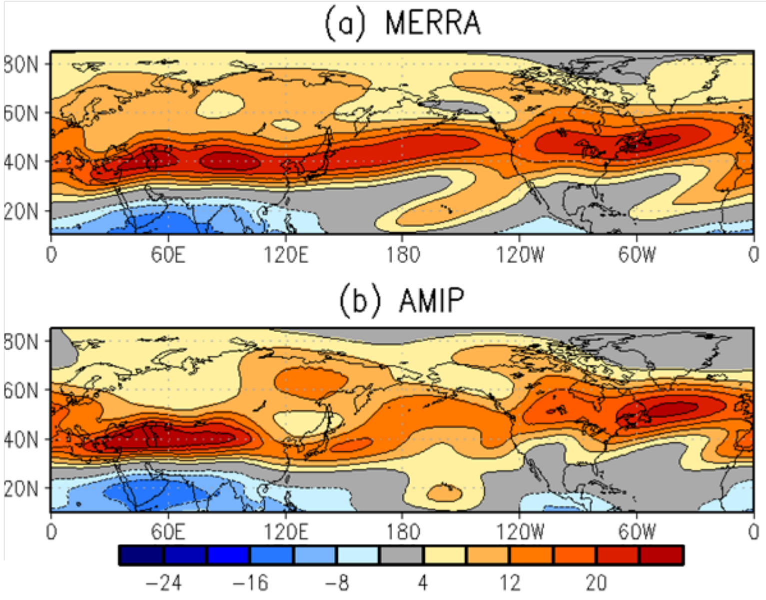


Rapid development of drought conditions over North America upon establishment of quasi-stationary circulation anomalies

A Case Study

- The 20May-15Jun1988 stationary Rossby wave event
  - Processes that led to rapid drought development and their representation in model hindcast
    - Stationary Rossby wave sources over western Pacific
    - North Pacific mean jet stream
    - Local soil moisture feedback
    - 20May atmospheric and land initial conditions
  - AGCM modeling approach

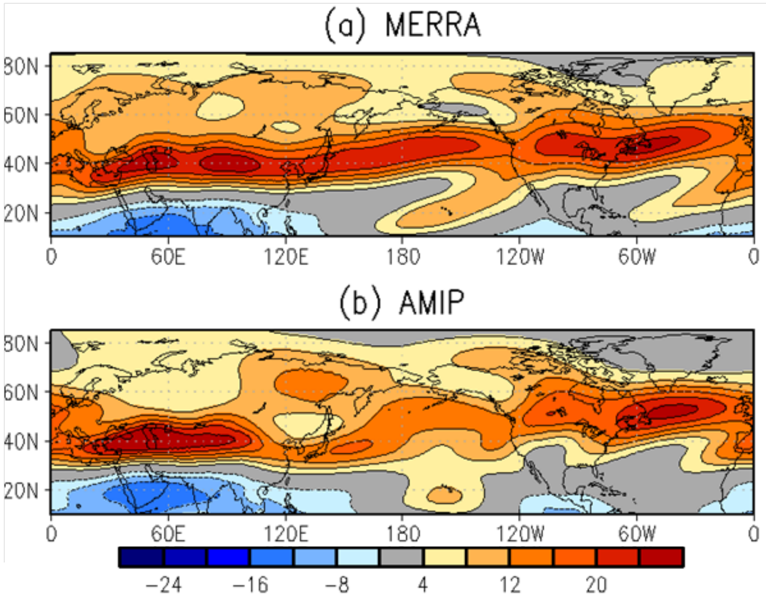
U250 JJAClim(1980-2010)



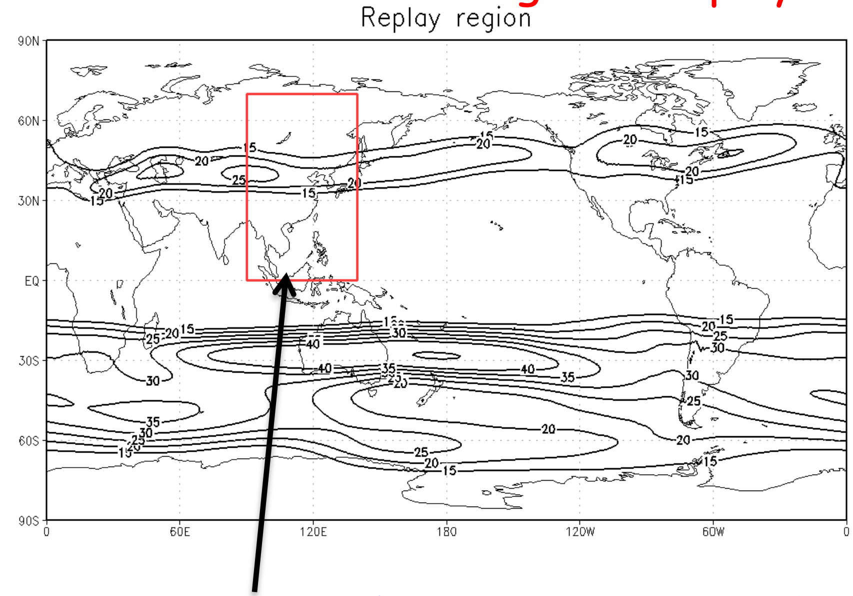
The use of free-running GEOS-5 AGCM is limited by its poor simulation of North Pacific mean jet stream:

- Model jet: weak and disoriented
- Similar biases seen in many other AGCMs

U250 JJAClim(1980-2010)

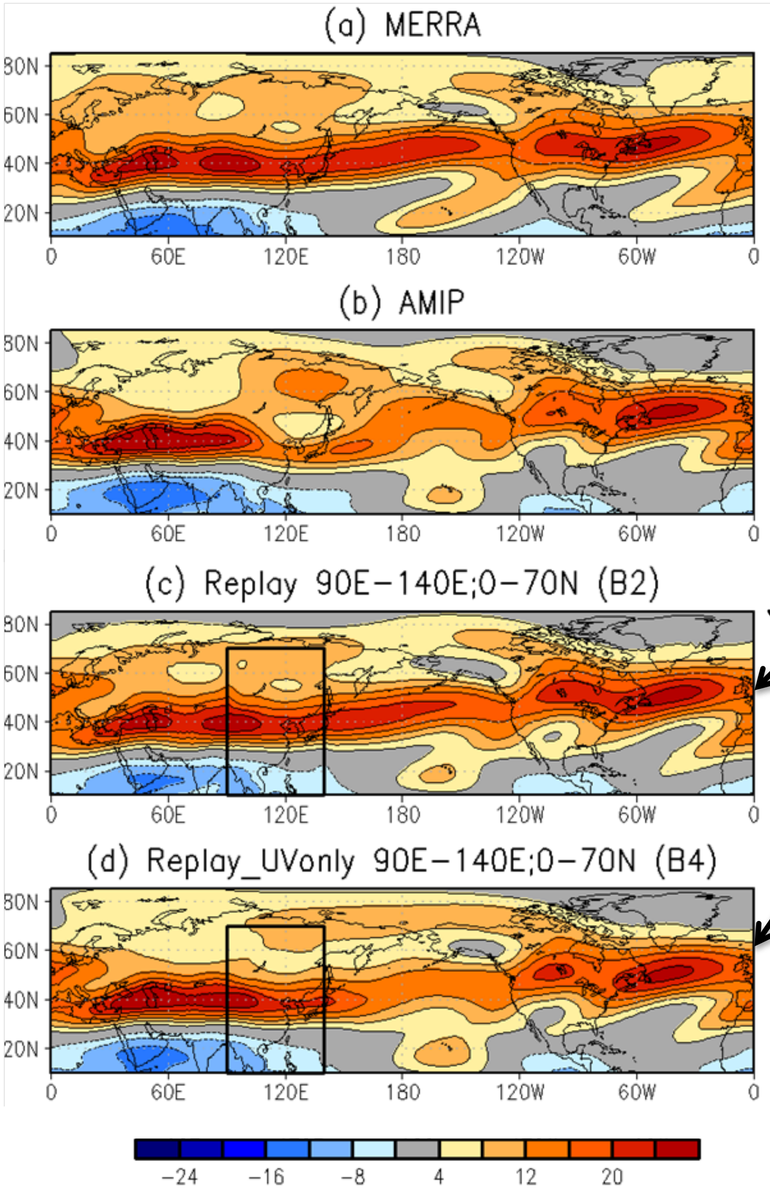


GEOS-5 AGCM regional replay

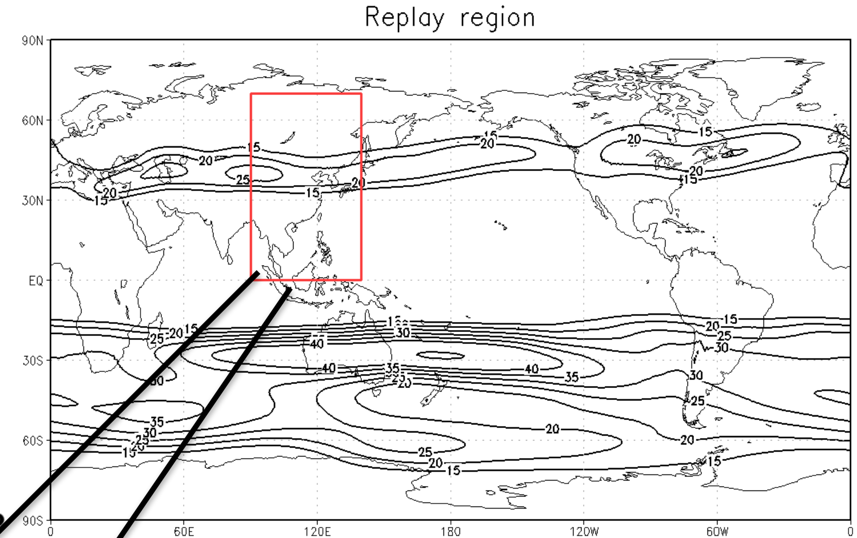


constrain model atmosphere to MERRA for limited regions and a subset of basic variables (U,V,T,Q,Ps)

U250 Clim: JJA



GEOS-5 AGCM regional replay



U,V,T,Q,Ps

U,V

Constraining model atmosphere to MERRA over E Asia and W Pacific:

1) removes most of model bias in north Pacific mean jet;
2) uses observed wave sources in the replay region

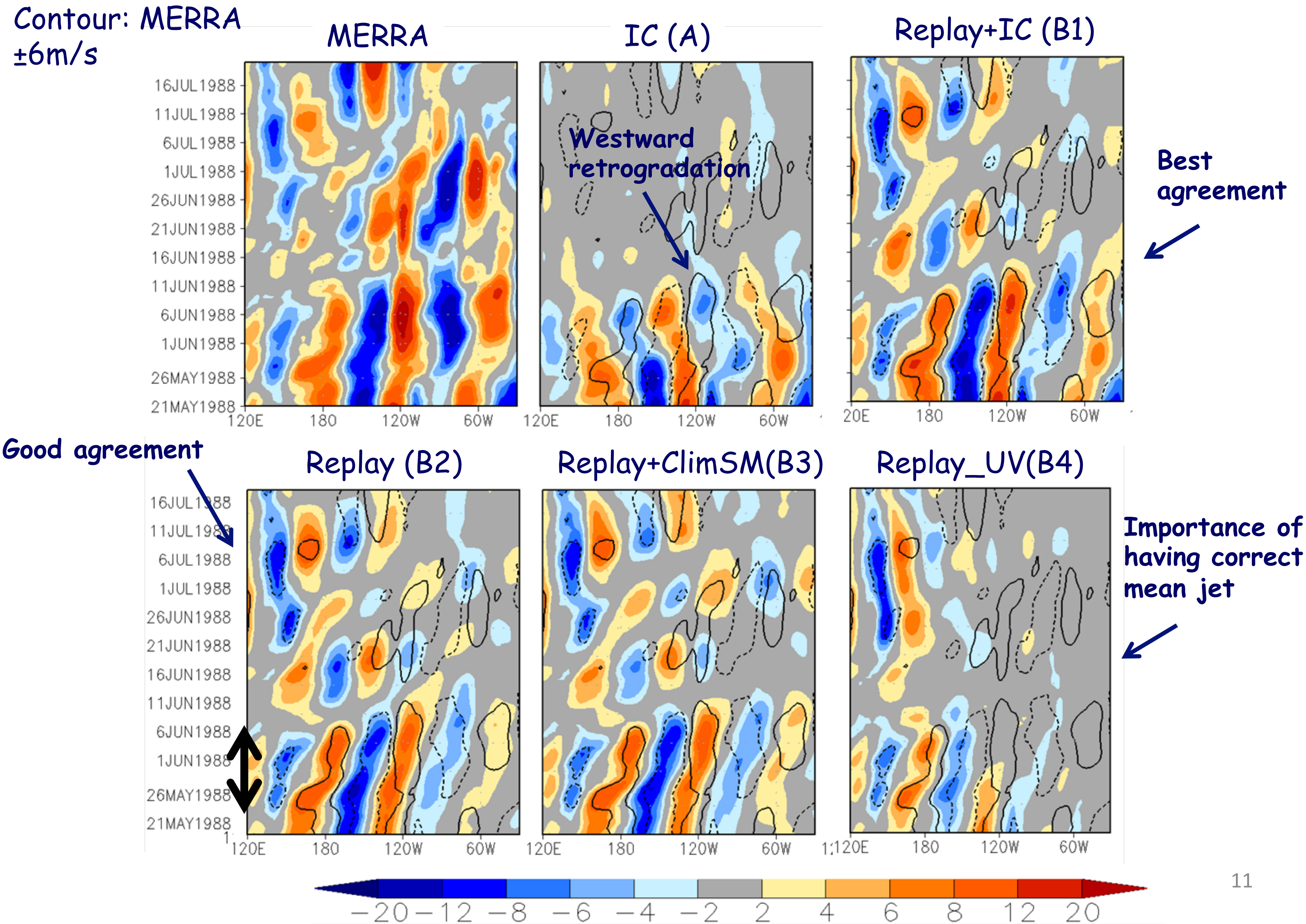
AGCM Experiments

Experiments	Replay region	Replay variables	Atmospheric and land initial conditions	Land feedback	Processes
A	N/A	N/A	*Control*: 21z, 20 May of 1980-2010 *Anomaly*: 21z, 20 May 1988 plus small atmospheric perturbations	Yes	1
B1	E Asia W Pacific	U,V,T,Q,Ps	Same as A1	Yes	1,2,3,4
B2			*Control*: 21z, 2 May of 1980-2010 *Anomaly*: 21z, 2 May of 1980-2009	Yes	2,3,4
B3			Same as B2	No	2,4
B4		U,V	Same as B2	Yes	2,3

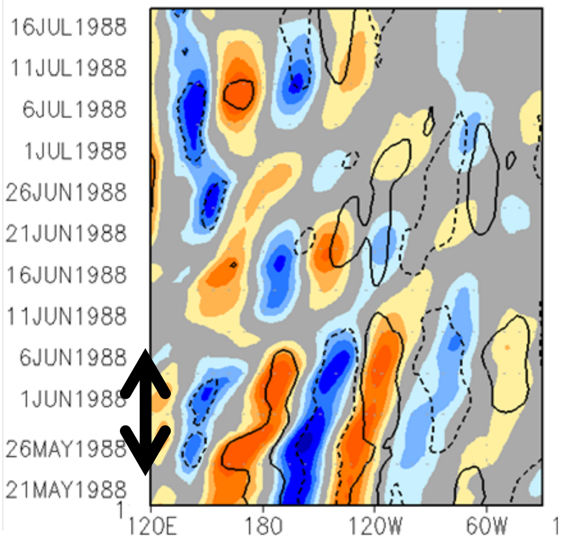
1: 21z 20 May 1988 atmospheric and land initial conditions
2: observed wave sources over western Pacific
3: soil moisture feedback
4: corrected model mean jet over north Pacific

GEOS-5 AGCM; 1deg; Each experiment consists of a control ensemble (31 members) and an anomaly ensemble (30 members).

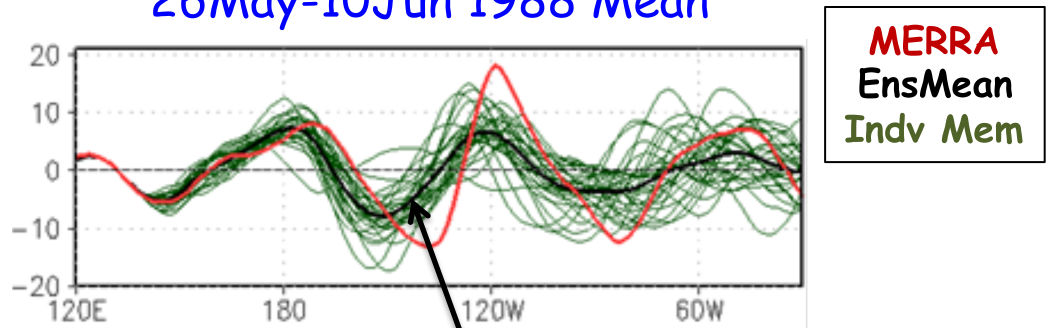
Time evolution of V250mb (30N-60N)



Replay (B2)

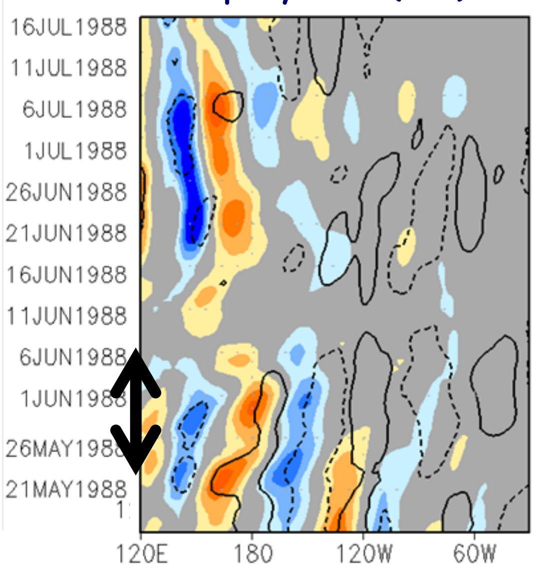


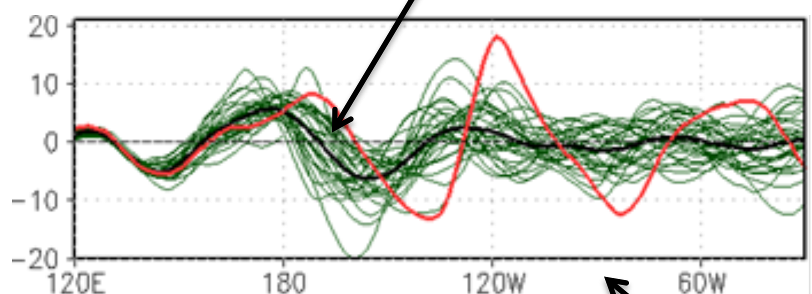
26May-10Jun 1988 Mean



Jet guides and constrains wave energy propagation path and speed

Replay_UV(B4)

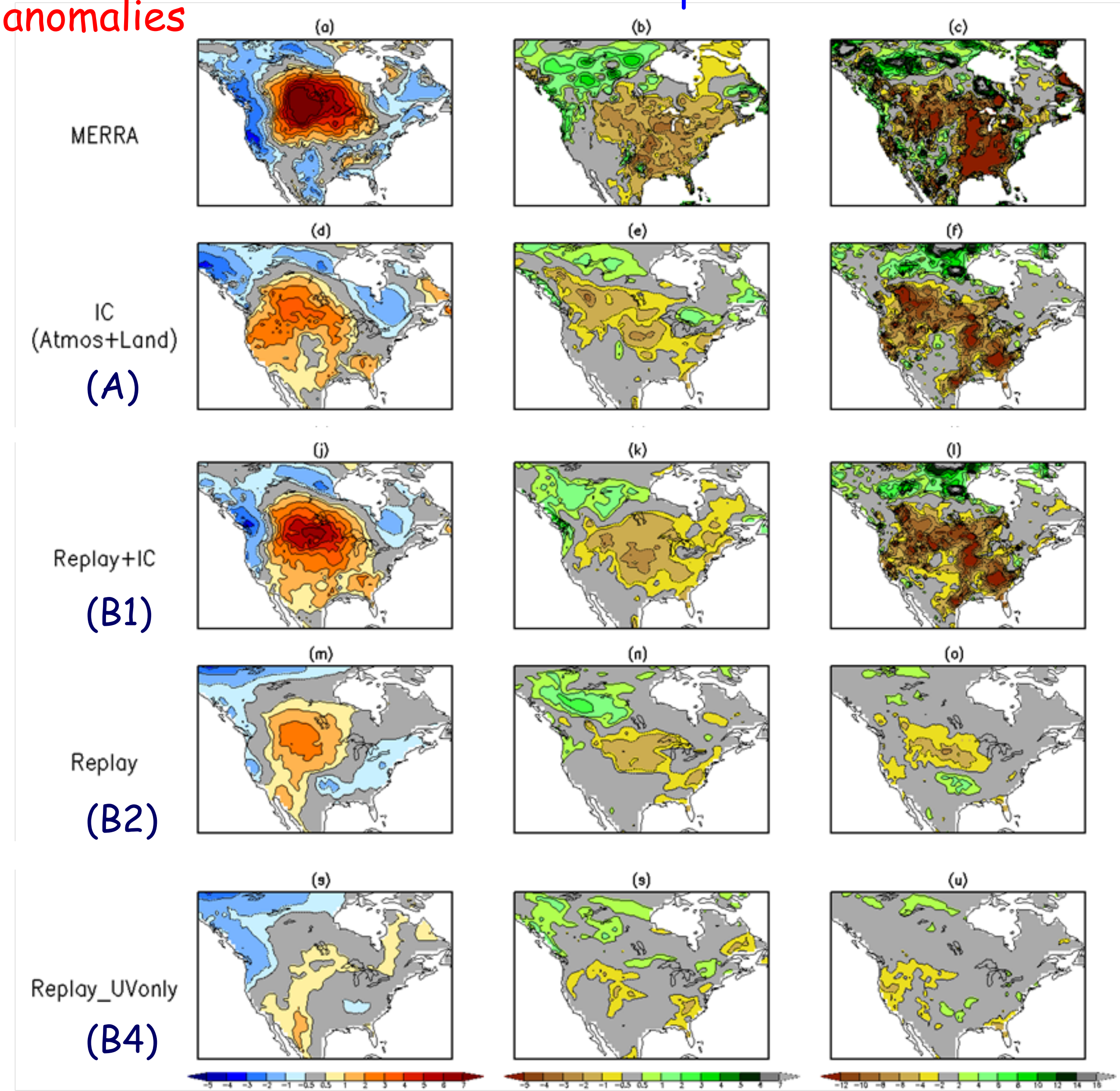




Weaker jet
Slower propagation
Larger spread

26May-10Jun 1988
mean anomalies

Ts | Precip | Soil wetness



Westward shift;
Still benefit from
atmos and land ICs

Best agreement

WPac Conv anom
+correct_Jet=>persistent
high over NA=>NA
drought

Critical importance to
have correct NPac mean
jet

Conclusions

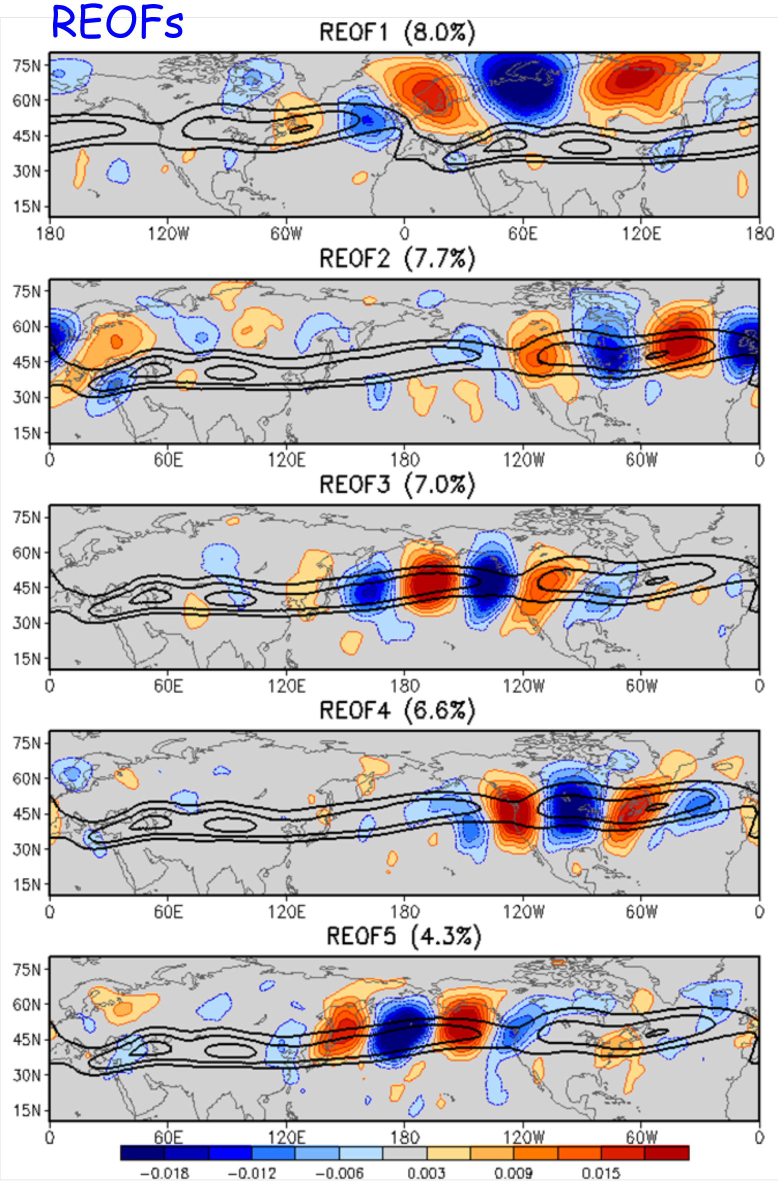
- Summertime stationary Rossby waves played a crucial role in subseasonal development of a number of North American droughts.
- A case study of a stationary Rossby wave event(20May-15Jun1988):
  - Critical importance of NH mean jet stream in guiding and constraining wave energy propagation path and speed
  - Convective anomalies over western Pacific in late May produce a predilection for persistent upper-level high anomalies over central North America about 10 days later, leading to the rapid development of severe dry conditions there
- Stationary Rossby waves can serve as a potential source of predictability for subseasonal development of droughts over North America and northern Eurasia
  - Critical importance to have correct NH jet streams (location, shape, magnitude) in GCMs
  - Future work: Predictability of stationary Rossby waves, including their origins

Extra Slides

Leading modes of subseasonal atmospheric circulation variability

REOF analysis of summer subseasonal V250mb (MERRA)

REOFs



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Strong guidance by NH mean jets

Fraction of subseasonal variance explained by top 10 REOFs